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INSECT AND OTHER ANIMAL PESTS OF RICE

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ANIMAL PESTS of rice range from field and storage insects to muskrats and waterfowl. Proper identification of the major pests is vital for rice growers, but it is also important to identify certain non-damaging types so as not to confuse them with harmful varieties.

THIS CIRCULAR

- tells how to recognize major rice pests
- suggests methods of control
- discusses non-harmful types
- explains methods of preventing damage

AN INTEGRATED CONTROL APPROACH designed to preserve proper ecological balance in and around rice fields is emphasized.

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R. L. Rudd .... section on birds as rice pests
E. W. Jameson .... section on muskrats and nutria as rice pests

INSECT AND OTHER ANIMAL PESTS OF RICE

INTRODUCTION

RICE is an important field crop in California's economy, ranging in gross value from 85 to 100 million dollars annually; about 400,000 acres are needed to grow it. Although weeds are one of the principal pests of rice, insect and other animal pests can occasionally be even more troublesome and costly. In 1953, for example, the rice leaf miner cost California rice farmers an estimated $16,000,000 loss in yield and $1,200,000 for control (after University of California research developed control measures). Muskrats, blackbirds, ducks and mudhens annually cause severe localized damage if not controlled, and over-all field yields may be reduced by infestations of tadpole shrimp, rice leaf miner, and other pests. A rice farmer should check his fields carefully and frequently to detect animal pests before serious damage has been done (this is why a roadway around each field is important). Recommended controls should be used promptly when needed. In some cases, crop rotation provides preventive measures; for example, growing a crop like safflower every few years on riceland destroys shelter in which rodents live.

The authors strongly recommend against so-called preventive applications of insecticidal chemicals, and urge that chemical control be used only when inspection shows that animal pests are approaching damaging proportions. (For more detailed information on specific pest control problems, we suggest you consult the latest "U.C. Pest and Disease Control Program for Rice" available from your local Farm Advisors or Agricultural Commissioners.) When chemical control methods are used, it is essential that they be those which research has shown to be useful and beneficial—such methods take into consideration not only residue safety factors but also the biological balance of predators and other forms of wildlife.

> Indiscriminate use of poisonous insecticides can often be costly and detrimental. If chemicals are used, they should be only those which have been officially registered for the purpose. Instructions on the manufacturer's label must be carefully followed.

FIELD INSECT PESTS

California rice is occasionally attacked by insect pests in all stages of its growth, and rice growers must be constantly alert to forestall serious damage. Known pests, and the stage of rice attacked, are listed on page 9. Only the more important insect pests of rice will be discussed in detail in this publication.

The rice leaf miner

The rice leaf miner, *Hydrellia griseola* (Fallen), is widely distributed in California. Flooding fields preparatory to planting rice in April and May, and availability of young rice plants, can result in sudden increases in populations. Al-

Fig. 1. Above: adult of *Chorebus aquaticus* Muesebeck, a parasite of the rice leaf miner.

Fig. 2. Left: adult male of rice leaf miner, *Hydrellia griseola* (Fallen).

Fig. 3. Below: adult of *Opius hydrelliae* Muesebeck, a parasite of the rice leaf miner.

though several parasites may assist in reducing numbers of the miner, the greatest reduction is caused by high temperatures in May and June. If these months are cool, the insect can feed longer and cause greater damage. Damage usually occurs in more restricted areas, especially in borrow pits or in checks where there is cool and excessively deep water.

Leaf miner adults are gray-colored, have a metallic green sheen, and are 1/8 to 1/4 inch long (females are often larger than males). The elongate (see GLOSSARY, page 32, for explanation of technical terms) white-ribbed eggs, 1/35 to 1/40 inch long, are laid singly on leaf blades and hatch in 3 to 5 days. The larvae mine leaf tissues, and loss of tissue gives leaves a transparent appearance if on the water, or causes them to turn pale yellow if above water. In severe attacks, maggots may also mine the leaf sheath; continued mining may cause the plant to die, although damage is primarily that of reduction of stand. Mining may also cause some delay in plant development.

The leaf miner larva attains a length of about 1/8 inch, and pupation occurs in the mined leaf; the third instar larva often migrates into another leaf to form a new mine prior to pupation. The larval period ranges from 7 days at 90°F. to 41 days at 50°F., and the pupal period varies from 5 days at 90°F. to 34 days at 50°F. Total developmental time is from 13 days at 90°F. to 94 days at 50°F. Numbers of generations depend upon temperatures, host-plant availability, and suitable high-moisture conditions; ten to

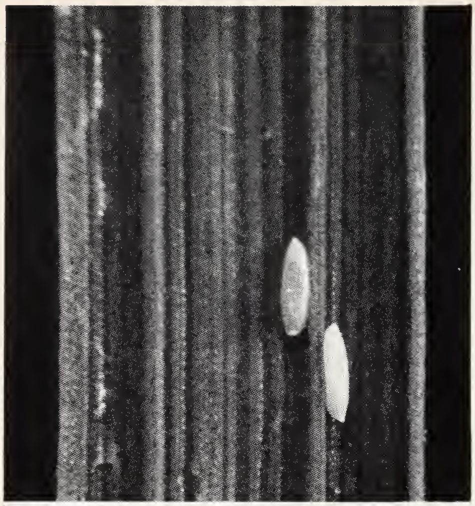


Fig. 4. Eggs of rice leaf miner, Hydrellia griseola (Fallen), on upper surface of rice leaf.

eleven generations a year can occur under optimum conditions. The flies often rest on blades of rice or grasses in rice fields, and they can walk on water from one plant to another.

Control. Control is accomplished through a combination of water management and insecticides. Deep water for the first 15 to 30 days after seeding, followed by a sudden lowering of water, often causes weak rice plants to lie prostrate on the water surface and this creates optimum conditions for oviposition and development of leaf miners. The problem can be especially acute in the deep water of borrow pits. To avert serious damage, start the crop in shallow water and gradually increase water depth to allow rice to emerge quickly and develop stout stems and erect leaves. Damage from leaf miner attack is often more serious in "cold water" checks because plant growth there is slower and leaf blades remain prostrate longer. Chemical sprays have been effective in controlling the adult flies and the maggots mining leaves (see "U.C. Pest and Disease Control Program"). Growers should examine leaves of seedling rice plants lying prostrate on the water surface; sprays should be used when eggs and new larval mines are abundant.

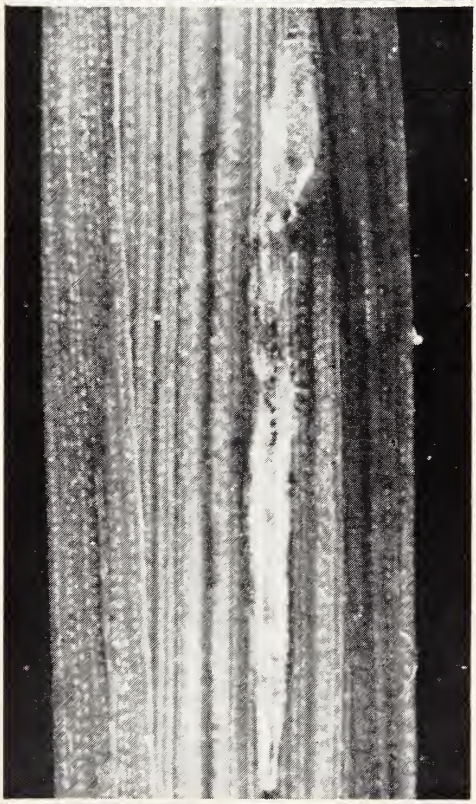


Fig. 5. Left: mine of rice leaf miner.

Fig. 6. Left, below: larva of rice leaf miner.

Fig. 7. Below: pupa of rice leaf miner in leaf mine.

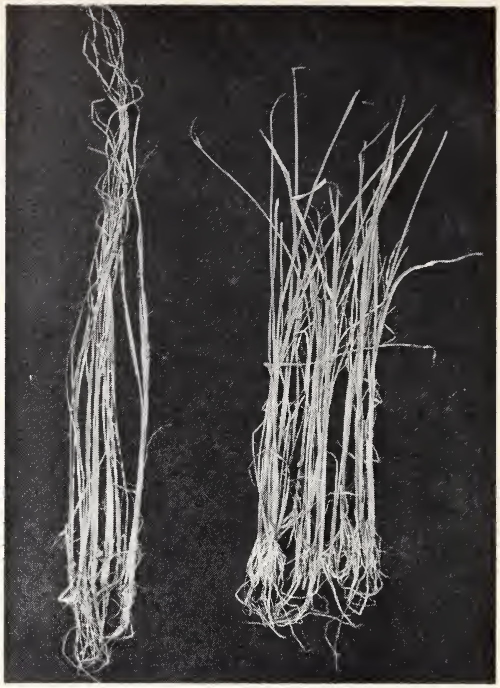


Fig. 8. Above left: rice plants in stage susceptible to rice leaf miner attack. Fig. 9. Above right: rice (left) from deep-water check showing extreme damage from the rice leaf miner; right, rice from same check in more shallow water showing light damage (same number of plants in each lot).

Rice water weevil

The rice water weevil, *Lissoroptrus oryzophilus* Kuschel, is found in Butte, Glenn, Yuba, Colusa, Sutter, Sacramento, and Yolo counties and judging by its importance as a major pest in the southern rice-growing states, is a potential threat to the rice crop. Males are unknown in California, indicating an accidental introduction of the weevil in the Biggs area prior to 1959, possibly by a single parthenogenetic female. Adults overwinter around the edges of fields where they are otherwise located at the bases or crowns of various weeds and grasses, particularly in species of *Paspalum*. They begin to feed on new grasses in March and April, and fly to rice fields in April, May and June. Weevils from spring flights can be found on grasses in irrigation laterals, or on the levees of flooded rice fields.

Adults move from grasses to rice when it emerges from the water, or they may appear diiectly on the rice if spring flights occur after rice emerges. Weevils feed on the leaves, causing characteristic longitudinal scar-like areas. The females crawl below the water line and deposit single eggs in leaf sheaths and (infrequently) roots. Eggs hatch in from 7 to 10 days—weevils have laid as many as 35 eggs per female in the laboratory.

The adult weevil is grayish-brown with a dark indistinct area on the back; it is about ⅛-inch long, and has a wide beak. In water it appears darker and may assume a greenish tinge. Eggs are elongated, white, slightly curved inwardly on one side with rounded ends and are about $\frac{1}{28}$ inch long and one-third as wide. The milky-white larvae are about ½ inch long when mature, are legless, and have light-

Fig. 10. Left: adults of rice water weevil.

Fig. 11. Left, center: damage to rice leaves by rice water weevil adults.

brown heads. Paired dorsal hooks—modified spiracles on each of the dorsal aspects of abdominal segments two to seven—are used for obtaining air from plant roots. Large breathing tubes (tracheal branches) can be seen inside the body.

After hatching, larvae mine the leaf sheath for a while and then crawl down the plant to its roots, on which they complete four instars. The pupae occur in earthen circular cells produced by the mature larvae. These ball-like structures are attached to the roots of grasses, sedges or rice, and they can be used in the field to confirm the presence of the weevil. The pupa inside the mud cell is white.

Adults emerge from pupal cells in rice fields from July through September (in fewer numbers than in May and June) and continue to reproduce in the same or neighboring rice until fields are drained in September. At 73°F. a typical life history is: approximately 7 days in the egg stage, 50 days as larvae, 21 days as pupae —about 78 days from egg to adult. Larvae ("root maggots") feed on roots and

Fig. 12. Below: earthen pupal cells of rice water weevil attached to the roots of water grass.

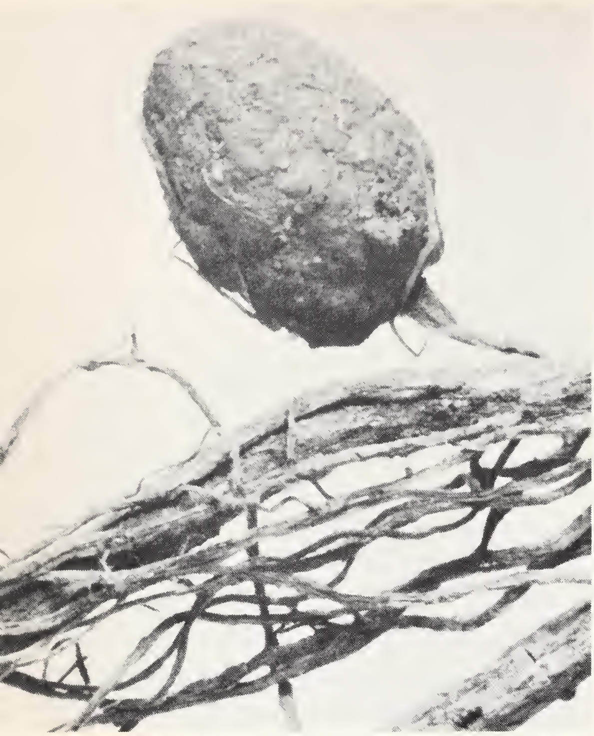


Fig. 13. Enlarged view of a single earthen pupal cell of rice water weevil.

cause a pruning of the root system; if numerous, they may cause stunting of the plants with consequent fewer tillers and significantly reduced grain yields. A caged population of one weevil per plant can reduce grain yield as much as 30 per cent. However, populations of this density have not been found in California rice except around margins of the fields.

Control. A recently registered carbamate insecticide effectively controls the weevil when applied to the soil surface or incorporated into the soil (to a depth of 4 inches) prior to flooding. This material is toxic to fish and wildlife and treated irrigation water should be kept out of lakes, streams or ponds for at least 7 days. Make only one application per season. If weevil damage is limited to the 25 feet immediately adjacent to the levees (determined by examination the previous year), treat this area only. If weevil damage is widespread or levees are close together, entire field treatment is necessary (for details see the latest "U.C. Pest and Disease Control Program").

Fig. 14. Left: two plants stunted by root pruning of rice water weevil. Right: undamaged plants.

Fig. 15. Close-up of damaged root system of a rice plant; arrows indicate two larvae.

FIELD PESTS OF CALIFORNIA RICE

Common name	Scientific name	Stage of growth attacked or type of damage, or both
Rice leaf miner	*Hydrellia griseola* (Fallen)	Young plants
Rice water weevil	*Lissoroptrus oryzophilus* Kuschel	Young to mature plants
Midges	*Cricotopus sylvestris* (Fab.)	Germinating seeds and leaves of seedlings
	Tanytarsus sp.	Germinating seeds
	Paralauterborniella subcinctum (Townes)	Germinating seeds
Rice leaf folder	*Lerodea eufala* (Edwards)	Young to mature plants
Western yellow-striped armyworm	*Prodenia praefica* Grote	Young to mature plants
The armyworm	*Pseudaletia unipuncta* (Haworth)	Young to mature plants
Leafhoppers	*Draeculacephala* sp.	Young to mature plants
	Exitianus exitiosus (Uhler)	Young to mature plants
	Nesosteles neglectus (Osborn)	Young to mature plants
	Macrosteles falcifrons (Stål)	Young to mature plants
Onion thrips	*Thrips tabaci* Lindeman	Young plants
Western flower thrips	*Frankliniella occidentalis* (Perg.)	Young plants
	Anaphlothrips longipennis (Crawford)	Young plants
Water scavenger beetle (adults)	*Hydrophilus triangularis* (Say)	Young plants
Tadpole shrimp	*Triops longicaudatus* (Le Conte)	Feeds on and uproots seedlings; muddies water
Crayfish	*Procambarus clarki* (Girard)	Muddies water, undermines weir boxes, burrows into earthen checks.
	Orconectes virilis (Hagen)	As in *Procambarus*

Plate 1. The rice leaf miner, Hydrellia griseola (Fallen).

Plate 2. The rice water weevil, *Lissoroptrus oryzophilus* **Kuschel.**

Occasional insect pests

A typical rice field abounds in various types of aquatic insects which are normally associated with semi-permanent ponds and which cause little or no crop damage. Particular species may sometimes become extremely abundant to the exclusion of others. These include mayflies (Ephemeroptera), giant water bugs (Belostomatidae), back swimmers (Notonectidae), water boatmen (Corixidae), and predacious water beetles (Dytiscidae). The Corixidae occasionally lay their eggs on stems or leaves of rice seedlings; their weight causes some damage, but otherwise they seem of little importance.

Small, non-biting midges of the family Chironomidae (Tendipedidae) are the commonest insects found in rice fields. About 30 different species have been reared, and many other forms occur in ditches and adjacent aquatic habitats associated with rice production. Adult midges resemble mosquitoes, but can be recognized in the field by their habit of holding their fore-legs well above the substrate when at rest. Mouth-parts of midges are undeveloped, and they lack the scales on wing margins and wing veins which are characteristic of mosquitoes.

The eggs of most midge species are laid in masses or strings held together by a sticky mucous material which swells

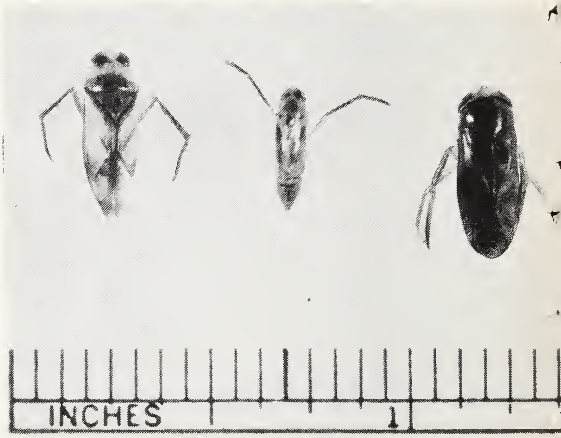


Fig. 16. Above left: giant water bugs (family Belostomatidae) commonly found in rice fields.
Fig. 17. Above right: center and left, back swimmers (family Notonectidae); right, water boatman (family Corixidae).

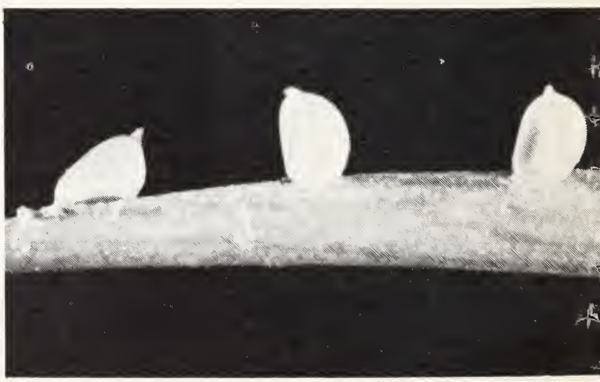


Fig. 18. Above left: large beetles commonly found in rice fields: Left, large scavenger beetle, Hydrophilus triangularis (Say); right, predacious diving beetle (family Dytiscidae).
Fig. 19. Eggs of water boatman on rice leaf.

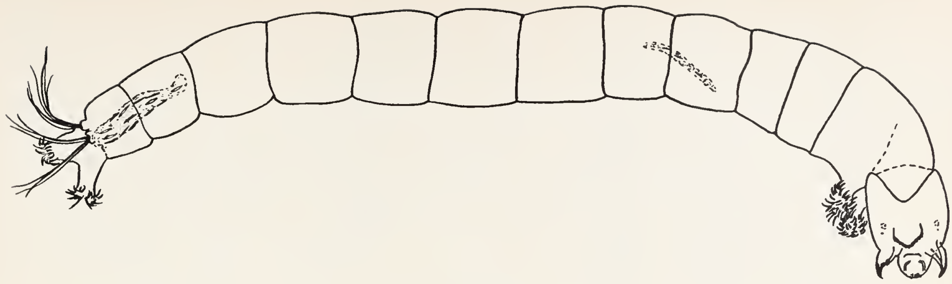


Fig. 20. Larva of a midge, Cricotopus sylvestris **(Fab.) X 70 (family** Chironomidae**).**

into a protective gelatinous envelope around the eggs when it comes in contact with moisture. Egg masses are usually present throughout a field before rice emerges, but later they are more often deposited in borrow pits or in other open water.

The larvae of most midges in rice fields feed on algae and microscopic particles of plant material, but a few are predacious and some species may feed on plant tissues. Larvae responsible for rice damage build tubes of silk and bits of algae or debris and live in them. Tubes may be located on the mud bottom of the rice check, on submerged and emergent vegetation, on the submerged portions of weir boxes, or on algae under water and/or floating on the surface.

Midge larvae damage rice seeds at the time of germination and also damage leaves. Injury to germinating rice was first observed in 1953 in San Joaquin County and has since occurred there periodically. In that county, several species, including *Tanytarsus* sp., *Paralauterborniella subcincta* (Townes), and *Cricotopus sylvestris* (Fabricius), are associated with damage to seeds. These pests feed on the soft growing points of the seedlings; they also burrow into the rice seeds and may cause complete destruction.

Damage to rice leaves is caused by the larvae of *C. sylvestris,* which feed on leaves floating on water (usually on deep water, such as occurs in borrow pits near edges of fields). *C. sylvestris* larvae build transparent protective silken tubes on the undersides of older rice leaves and feed from the open ends of these tubes, eating small holes completely through the leaves (unlike the rice leaf miner, which does not eat through the upper epidermis of the leaf). Old rice leaf miner damage in which the upper epidermis has disintegrated may resemble and be mistaken for midge damage.

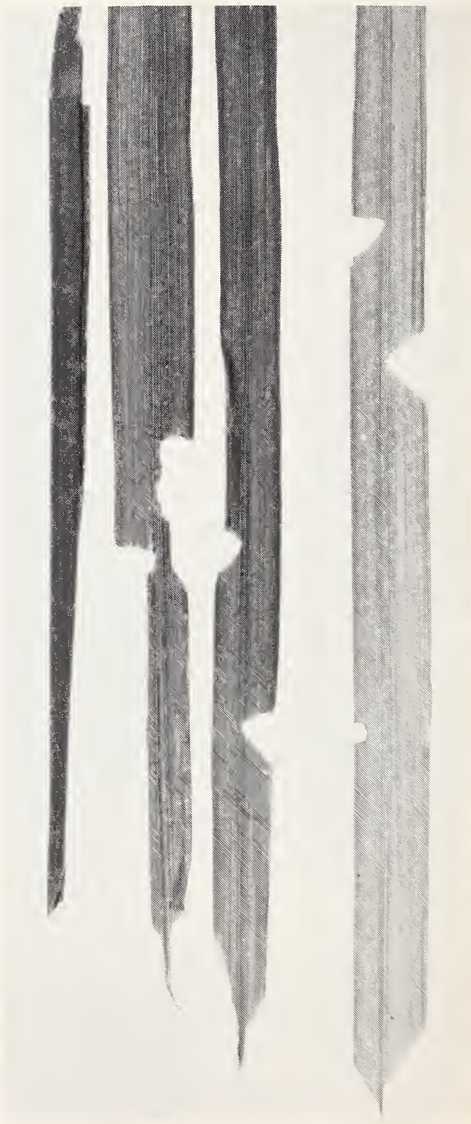
Similar damage to rice in other areas of the world is reportedly caused by the larvae of a closely related species, *Cricotopus trifasciatus* Panzer. Another related species, *C. bicinctus* (Meigen), is not known to damage rice although it is abundant in California rice fields.

No chemical control for midges has been considered necessary. It has been observed that fields high in organic matter (due to discing up alfalfa or hay crops prior to planting rice) often harbor high populations of midges.

Adults of the larger scavenger beetle, *Hydrophilus triangularis* (Say), are commonly seen in the water after a field is submerged, but they rarely appear in abundance. Females lay eggs in silken cases which may float or which can be attached to floating objects. Adults may cut rice leaves to form a float for attachment of the egg case; they may also dislodge small seedlings with their swimming activity. Adults normally feed on algae, but larvae are predacious on other aquatic organisms. They may be several

Fig. 21. Above: damage to old rice leaves caused by a midge, *Cricotopus sylvestris* (Fab.) (family Chironomidae).

Fig. 22. Adult rice leaf folder.



inches long when mature and thus could mechanically uproot seedlings, but seedlings are usually large enough by then so that such damage is unlikely.

The rice leaf folder, *Lerodea eufala* (Edwards). Larvae of this skipper butterfly occasionally feed on rice leaves, producing an angulate feeding pattern. This species also feeds on a number of grasses and on sorghum and sweet corn. The large, yellowish globular eggs are laid singly on the upper surface of the leaf. The caterpillars are over 1-inch long when mature, and often conceal themselves within a roll of the leaves. No fecal pellets are found near the larvae, as they are forcibly ejected 8 to 12 inches away. The larva is a dull light-green, with a white subspiracular band extending from the anterior margin of the second abdominal segment to the posterior margin of the eighth abdominal segment. It also has a light cream-colored supraspiracular band and a wider cream-colored subdorsal band extending from the anterior mar-

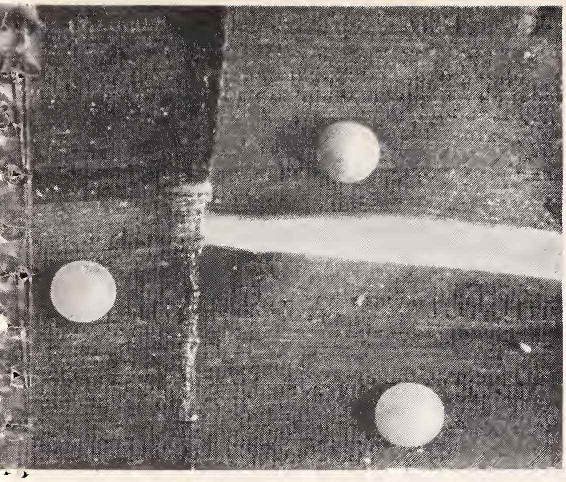


Fig. 24. Eggs of rice leaf folder.

gin of the metathorax to the end of the body. The body of the larva tapers anteriorly and posteriorly, and the head is very prominent. The pupae are green and have a characteristic anterior projection. They are supported on the leaf by a button of silk posteriorly, and anteriorly by a series of silken threads forming a sling around the thorax so it can hang from the midrib of a rice blade.

The western yellow-striped armyworm, *Prodenia praefica* (Grote), and the armyworm, *Pseudaletia unipuncta* (Haworth), are well-known members of the cutworm family (Noctuidae) which have occasional epidemic outbreaks in rice, even though rice is not a preferred host of these worms. *P. praefica* sometimes moves out of adjoining alfalfa in epidemic numbers, feeding on emergent vegetation in rice fields; when the more succulent plants are consumed the caterpillars move to the rice itself and cause extensive defoliation. *P. unipuncta* often feeds on wild and cultivated grasses, and attacks on rice occur adjacent to weedy areas or cultivated grassland areas. Chemical control of cutworms is sometimes required to protect rice from epidemic numbers.

◀ Fig. 23. Typical larval feeding of rice leaf folder.

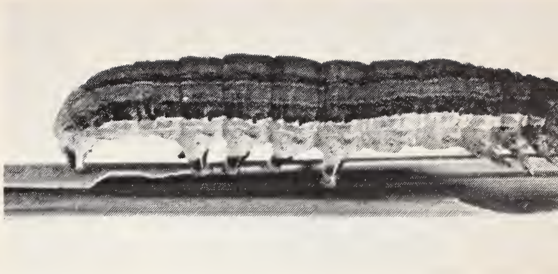


Fig. 25. Larva of armyworm, *Pseudaletia unipuncta* (Haworth) feeding on rice foliage.

Leafhoppers of several species often feed as nymphs and adults on rice, causing a yellow speckling of the leaves and, sometimes, stunting of the young plants. Numbers may occasionally reach epidemic proportions and may require chemical control. Common species found in-

Fig. 26. Left, rice damaged by armyworm; right, undamaged rice.

clude *Draeculacephala* sp., *Exitianus exitiosus* (Uhler), *Nesosteles neglectus* (Osborn), and *Macrosteles falcifans* (Stål).

Several thrips species occasionally attack young rice plants, causing a silvering, spotting, and a distortion of leaves. The common species involved include *Thrips tabaci* (Lindeman), *Frankliniella occidentalis* (Perg.), and *Anaphlothrips longipennis* (Crawford). Control has not been necessary as the plants outgrow this damage.

Several species of aphids occur on rice. The commonest include *Rhopalosiphum rufiabdominalis* (Sasaki); the English grain aphid, *Macrosiphum avenae* (Fab.); the waterlily aphid, *Rhopalosiphum nymphaeae* (L.); and *Rhopalosiphum padi* (L.). Chemical control has not been necessary.

MOSQUITOES

Mosquitoes are frequently a by-product of rice culture in California, and control of them is especially important because two of the several species found in rice-producing areas are involved in transmitting human diseases. The two are: *Culex tarsalis* Coquillett, the vector of viral encephalitis, and *Anopheles freeborni* Aitken, the vector of malaria. Other mosquitoes found in rice fields are important primarily as pests; they include *Aedes melanimon* Dyar and *Aedes nigromaculis* (Ludlow).

Culex and *Anopheles* mosquitoes deposit their eggs on the water surface. After a short incubation period the larvae hatch, and their life cycles are completed in the same manner as the *Aedes* species.

Culex and *Anopheles* mosquitoes are produced throughout the season when fields are flooded. *Culex* species usually reach maximum numbers in mid-summer, but *Anopheles* species peak just before the fields are drained for harvesting.

All immature stages of mosquitoes are aquatic. *Aedes* species deposit eggs on moist soil which has been previously flooded, and the eggs hatch when the area is reflooded. Four larval instars, followed by a pupal stage, complete their development in the water. After emergence the females mate, feed on animal blood, and deposit eggs; the cycle is then repeated. *Aedes* mosquitoes may be produced from rice fields when they are first flooded, or when cultural practice includes alternate drying and flooding of the soil surface.

Several available insecticides will economically kill mosquito larvae in rice-field water with no damage to the crop, but the cost of aerial application may make control fairly expensive.

Biological control of mosquito larvae and pupae by fish. The topminnow or mosquito fish, *Gambusia affinis* (Baird and Girard) is the most common fish introduced into rice fields for this purpose. It is a hardy, rapid breeding, prolific surface-feeding fish which thrives best in the moderately warm and comparatively shallow water found in most rice fields. These fish will also feed on crustaceans, chironomid midges, and many other common aquatic organisms. Several species of "instant fish" have been tested for mosquito control in California rice fields, but methods have not yet been worked out for their effective use.

Proper cultural practices to minimize mosquito breeding. Seepage and terminal drain water should be removed, and peripheral borrow pits should be promptly drained. To facilitate this, a properly engineered layout for water application and removal is important. Rank vegetation on field levees should be avoided, and internal borrow pits should

Fig. 27. Adult female mosquito, Culex tarsalis **Coq., the vector of viral encephalitis.**

Fig. 28. Adult female of an Anopheles **mosquito.**

Fig. 29. Egg raft of a culicine mosquito.

Fig. 30. Larvae and pupae of a culicine mosquito projecting downwards from water surfaces.

Fig. 31. Right: close-up of a larva and pupa of a *Culex* mosquito dangling from a water surface.

Fig. 32. Below: eggs of an *Aedes* mosquito.

not be choked with algae. (Rice growers regard algae as undersirable if growth is heavy enough to shade out young rice seedlings. Algae serve to protect mosquito larvae as well as to provide food for them.) Levees designed for re-use should be cleared by grazing or by an approved soil sterilant, or should be reshaped annually. Permanent or fall-prepared levees should be cleared by burning or by herbi-

Fig. 33. Flooding of a rice field. Seepage area in foreground full of weeds and organic matter is favorable for breeding of mosquito species, Anopheles freeborni **and** Culex tarsalis.

cides before starting the rice crop. Internal levee borrow pits should be graded to field level to allow rice-growth close to the levees.

Controlling algae with copper sulfate (blue stone) or other algicides generally control mosquitoes simultaneously, although certain species of blue-green algae apparently may serve as mosquito control agents. Some species of blue-green algae (*Tolypothrix, Anabaena,* and *Aulosira*) render rice-field water lethal to mosquito larvae. Some of these are nitrogen-fixing organisms which may also benefit rice culture; because their growth form is such that large mats do not accumulate, they do not adversely affect rice germination or seedling growth. These algae are being studied in the hope of developing a natural control method for rice-field mosquitoes.

Complete incorporation or coverage with soil of all organic matter, including green manure cover crops and previous crop residues in spring seedbed preparations, is important. Fields in which previous crop residues were incompletely covered prior to flooding and seeding have scum or algae and consequent stand-establishment problems; they are also heavy producers of mosquitoes.

Rice growers are legally obligated to reduce the numbers of mosquitoes originating from rice fields as much as is reasonably possible. See your Mosquito Abatement District Office for information about these requirements.

Insects damage rough rice by feeding and by causing the grain to heat; the moisture and body heat given off by pests results in "hot spots" in rice which damage grain quality. Primary insect pests of rough rice are the lesser grain borer, *Rhyzopertha dominica* (Fab.); the Angoumois grain moth, *Sitotroga cerealella* (Oliv.); and the rice weevil, *Sitophilus oryzae* (L.).

The adult lesser grain borer is a cylindrical, polished, dark brown or black beetle about 1/8 inch long. The female lays its eggs singly or in clusters in the lose grain; the larvae feed on flour produced by adults, or bore directly into damaged kernels.

The Angoumois grain moth is a small, buff or yellowish-brown moth with a wing expanse of about 1/2 inch. The female lays its eggs in or near the grain; upon hatching the small, white larvae eat their way into kernels where they complete their development.

The rice weevil is a reddish-brown snout beetle less than 1/8 inch long, usually having four slightly-pale areas on its wing covers. It attacks only grains with broken hulls or hulls not closed after blooming. The female deposits its eggs in the kernel where the larvae complete their development.

Secondary insect pests attacking stored rough rice are: the cadelle, *Tenebroides mauritanicus* (L.); the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.); the flat grain beetle, *Cryptolestes pusillus* (Schön.); and the Indian meal moth, *Plodia interpunctella* (Hbn.). These feed on the surface of the kernels, on broken grains, and on kernels damaged by boring insects.

The adult cadelle is an elongate, dark-brown or black beetle about 1/4 to 3/8 inch long. The female lays its eggs in batches in grain and larvae feed on it; when development is completed they leave the food and bore into wood.

The saw-toothed grain beetle is a brown beetle about 1/8 inch long with a row of saw-like teeth along the sides of the thorax. The female lays its eggs in cracks and crevices of grain; the larvae crawl about and feed randomly.

The flat grain beetle is a reddish-brown beetle about 1/16 inch long with long antennae. The female lays her eggs loosely in the grain; upon hatching the larvae feed and wander about the grain.

The Indian meal moth has a wing spread of about 5/8 inch. The outer two thirds of the forewings is coppery-brown and the remaining one-third is a pale gray. Eggs are laid in the grain; the larvae feed randomly in the grain, and when development is completed they come to the surface and spin cocoons. Thus, infested grain is always full of webbing.

Several species of pests found in grain do little damage but are annoying when present in large numbers (such pests are usually associated with damp, dark conditions). The most common of these are the psocids (*Liposcelus* spp.)—pale insects about the size of the head of a pin.

Control. To prevent damage in commercial grain storage, frequent inspection is essential. Chemical fumigants and protectants can be added to the grain as it goes into storage, and gaseous fumigants can be used in air-tight structures after rice is in storage.

For farm storage metal bins, proper sanitation is also essential. Bins must be cleared and sprayed prior to using with an approved insecticide if necessary, and birds and rodents must be kept out. For flat storage and for metal bin storage, all weeds must be cleared away from around installations. Approved insecticides should be sprayed on interior and exterior building surfaces prior to storage.

The tadpole shrimp, *Triops longicaudatus* (Le Conte), which resembles tadpoles in size, color, shape and mobility, came forcibly to the attention of rice growers in the spring of 1946 when it suddenly appeared in large numbers in rice fields of Butte and Sutter counties, chewing up seedlings and muddying water in the checks. Distribution was fairly general in the area with most growers reporting their presence even though damage did not occur in every instance. This crustacean is ordinarily a harmless inhabitant of temporary fresh-water pools, and normally had been mainly of academic interest only.

Specimens vary in size and in certain morphological characters. Adults vary from about 1¾ inches to nearly 3 inches in length. The forepart of the body is covered by a thin, olive-brown, sclerotic shield (the carapace) which is attached to the body only at the anterior end. The carapace can be lifted to expose most of the body, which is composed of about 35 segments or body rings. Of these, all but the last six (and sometimes seven) have pairs of leaf-like gill-bearing appendages. A pair of long spinous processes, the cercopods, extend from the last segment. True antennae are present but inconspicuous. The well-developed mouth parts include a pair of strong mandibles which enable it to chew. Long, jointed, antenna-like processes extend laterally from some of the mouthparts.

Fig. 34. Dorsal (left) and ventral (right) aspects of tadpole shrimp adults.

In California rice fields, *Triops* consists of females only—the eggs develop without fertilization by sperm. Twenty-five to thirty-five round orange-colored eggs are stored in a pair of capsules (brood pouches) on the eleventh pair of appendages which are near the posterior margin of the carapace. The eggs, about $\frac{1}{50}$ inch (0.5mm) in diameter, are highly resistant to desiccation and may remain viable for several years in the dried condition. Although some eggs may develop into larvae just after laying, eggs ordinarily remain dormant and do not develop until after a period of drying. Any population encountered is probably one which has developed almost entirely from eggs laid in some previous year.

After submersion in water tiny free-swimming larvae may develop from eggs as early as 3 days, but hatching may continue for 1 to 2 weeks. Larvae develop rapidly, resembling young adults in less than 24 hours. Several molts occur until adult size is reached, and these floating molt skins are sometimes mistaken for dead shrimp. On the ninth day after hatching, the animals become active "diggers," using their numerous appendages to stir up the silt on the surface of the substratum causing water to cloud. (Egg

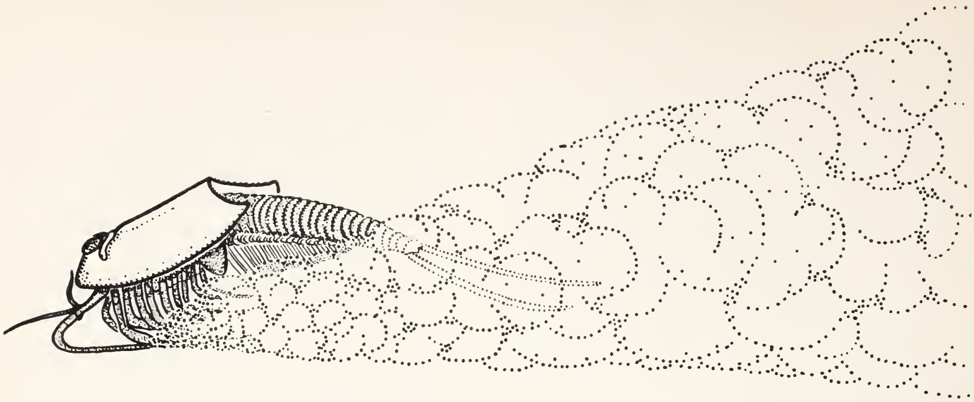


Fig. 35. Above: digging activity of tadpole shrimp foraging along substrate and leaving a trail of fine silt suspended in water.

Fig. 36. Second type of digging activity of tadpole shrimp, creating a dense cloud of silt suspended in water.

production begins at this same time.) Much digging occurs near the bases of the rice seedlings and is also accompanied by chewing of the plants. This may uproot entire seedlings, or the tender leaves may be chewed off and left to float to the surface of the rice check. Subsequent wind action brings masses of such leaves and seedlings into windrows against the dikes. If mature shrimps are present when the coleoptiles are emerging from the seed, their continuous feeding may prevent or delay germination.

Tadpole shrimp are not necessarily evenly distributed through a rice field, and muddy water makes it difficult to visually estimate populations. Fields with a history of tadpole shrimp infestations are more likely to have them in subsequent years. Simultaneous or early maturity of individuals, coincident with early or slow development of rice seedlings, increases chances of damage. A reduction of 25 per cent of the rice-plant stand was shown in a study in which shrimp were caged with the plants at a rate of eight shrimp per square foot. Serious outbreaks of *Triops* do not occur regularly, but a presently unknown combination of climatic and cultural conditions (including moisture, temperature, reflooding, etc.) may increase populations enough to cause considerable damage at stand-establishment time.

Fig. 37. Damage of tadpole shrimp to seedling rice.

Control. Control measures should be taken as soon as digging activity or damage are observed, and chemical control is often considered necessary. The period of damaging activity in California rice fields is usually short; by early June, rice plants are large enough to be no longer tempting to *Triops*. The shrimp's reproductive period ceases about this time, and the population soon disappears normally.

Fig. 38. Effect of tadpole shrimp on growth of rice; left, damaged; right, undamaged.

MISCELLANEOUS INVERTEBRATES FOUND IN RICE FIELDS

Many other invertebrate animals, from protozoans to sizeable worms and crustaceans, regularly occur in flooded rice fields. Most of these develop from resistant eggs or cysts deposited in bottom mud by the previous year's forms before the water disappears, and their life spans are usually brief. In some species, however, eggs may remain viable even though dormant for many years and will hatch when proper conditions are provided. Even adults of some pond organisms (notably rotifers) may dry up and remain so for years, but will revive when again im-

mersed in water. Resistant eggs and cysts may be transported from place to place on the feet of water birds or airborne in dust. Some forms, such as burrowing crayfishes, may exist through a dry period as dormant adults embedded in moist mud.

Many types of pond invertebrates multiply either asexually or from unfertilized eggs for several generations before the water disappears, thus building up large populations in a short time. Only a few of these invertebrates do any appreciable damage to plantings, although many forms are so abundant that growers are understandably alarmed. The damaging exceptions are the tadpole shrimp and insect pests already discussed, certain crayfishes, and (possibly) some snails, and oligochaete worms; the latter are discussed below.

Common aquatic invertebrates other than insects

Microscopic—or barely visible

Protozoa, Gastrotricha, Rotifera, etc. None of these forms are of any direct economic importance in rice fields.

Macroscopic—small but readily seen

Unsegmented worms

Flatworms or planarians (*Turbellaria*)
Roundworms (*Nematoda*)
Horsehair worms (*Nematomorpha*)

Annelid (segmented) worms

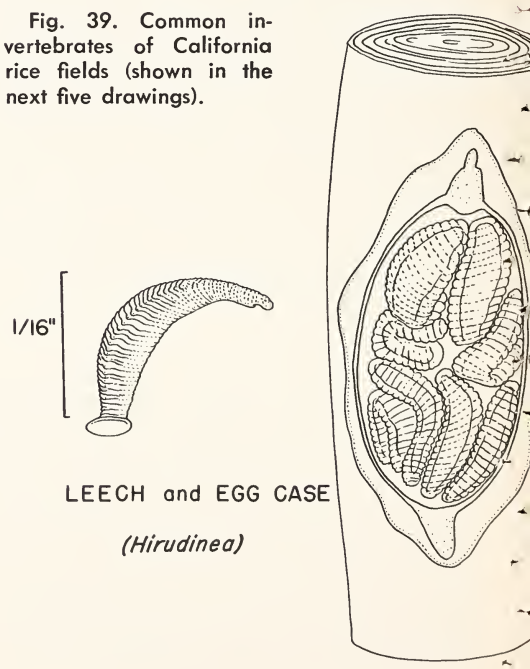
Leeches (*Hirudinea*). With suckers at one or both ends. Lay eggs in capsules cemented to rice plants but do no direct damage. No control necessary, although of possible economic importance.

Redworms (*Oligochaeta*). Related to earthworms. Often form writhing masses in mud with tails protruding. When abundant, they may loosen and uproot young rice plants, but as they lack jaws they do no direct damage though of possible economic importance. Control; bluestone (copper sulfate) applied as for pond snails (see below) is suggested.

Molluscs

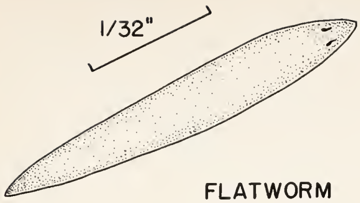
Pond snails (Gastropoda). Numerous kinds; all feed on aquatic plants by rasping leaves with their file-like tongues. Although of possible economic importance, they are not regarded as serious pests in rice fields unless overly abundant. Control: bluestone (copper sulfate) applied at the rate of 1 part to 200,000–250,000 parts water is suggested.

Fig. 39. Common invertebrates of California rice fields (shown in the next five drawings).



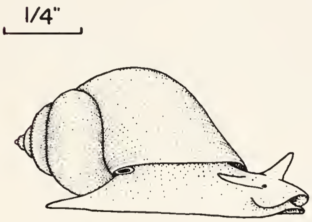
LEECH and EGG CASE

(Hirudinea)



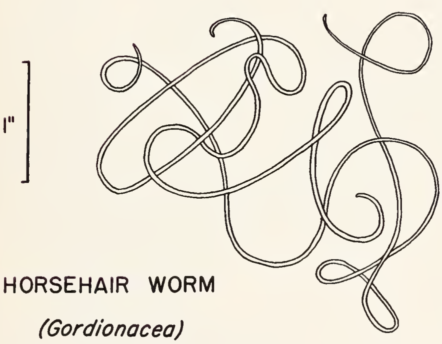
FLATWORM

(Turbellaria)



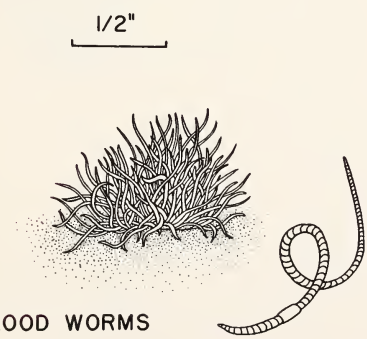
SNAIL

(Gastropoda)



HORSEHAIR WORM

(Gordionacea)



BLOOD WORMS

(Oligochaeta)

Clams (*Pelecypoda*)

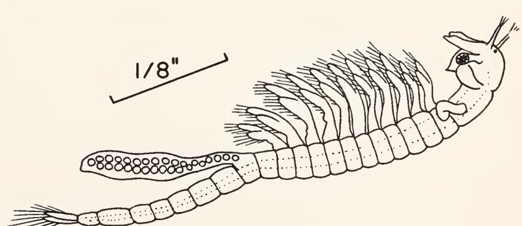
Fresh-water clams (e.g. *Anodonta, Corbicula*) occur in rice-growing areas but have not been reported in rice fields. The only one that might cause trouble is the Asiatic clam, *Corbicula fluminea* (Müller), which is now well established in the Sacramento-San Joaquin Delta and which has been reported in several lakes, streams, and irrigation ditches in this region as well as in southern California. There have been many complaints about their clogging pipe-lines, sprinkler systems, etc. which draw water from sloughs infested with these clams. In the Delta-Mendota Canal they form massive beds that significantly reduce the canal's water-carrying capacity. To date, there have been no complaints of their clogging irrigation ditches or boxes, but the potential exists.

Control of clams. Screening intakes has proved ineffective, as the microscopic larvae or tiny young go through the meshes. (Unlike most fresh-water clams, they require no obligatory fish host for larval development.) No inexpensive or feasible chemical treatment has yet been found, but copper sulfate or chlorine have been suggested. At present, physical measures such as dredging or flushing are employed for control.

Crustacea

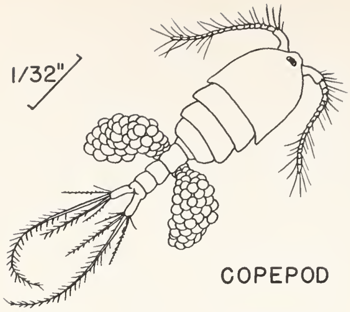
Tadpole shrimp (*Branchiopoda-Notostraca*). Because of its greater economic

Fig. 40. Immediately below: common crustacea of California rice fields (drawings continued next page).



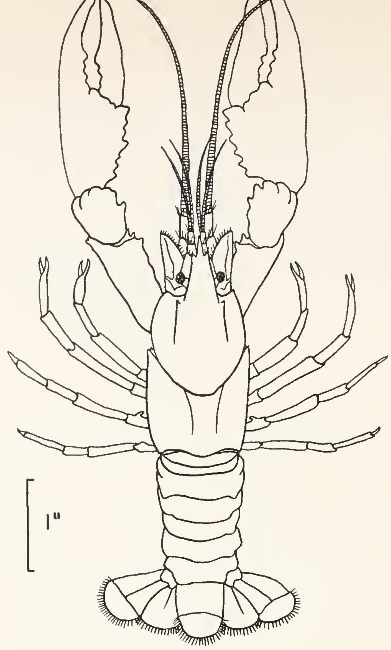
FAIRY SHRIMP

(Anostraca)



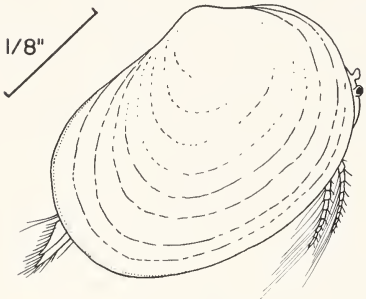
COPEPOD

(Copepoda)



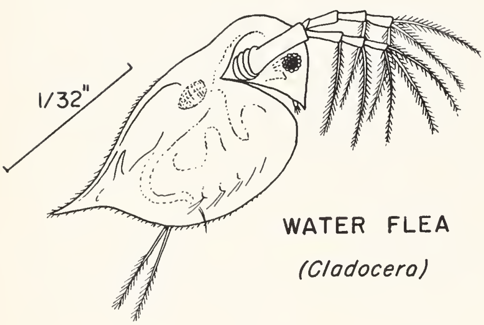
CRAYFISH

(Decapoda)



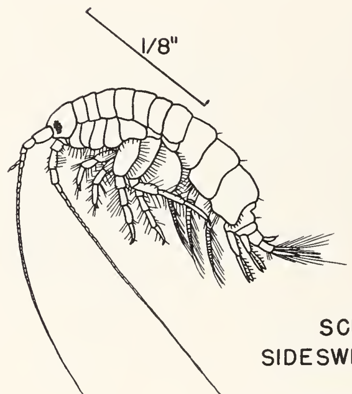
CLAM SHRIMP

(Conchostraca)



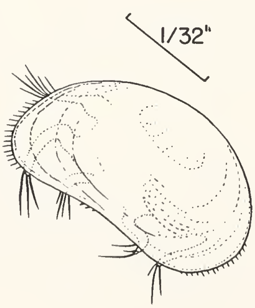
WATER FLEA

(Cladocera)



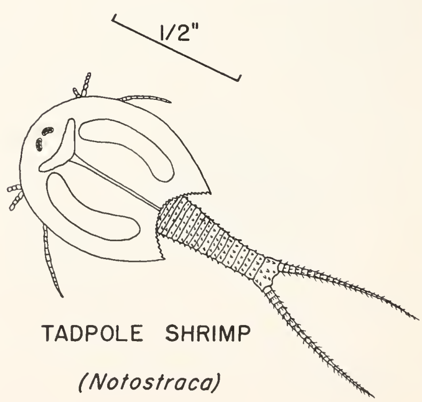
SCUDS
SIDESWIMMERS

(Amphipoda)



SEED SHRIMP

(Ostracoda)



TADPOLE SHRIMP

(Notostraca)

importance, this pest has been discussed in a separate section but is shown above.

Fairy shrimps (*Branchiopoda-Anostraca*).

Clam shrimps (*Branchiopoda-Conchostraca*).

Water fleas (*Branchiopoda-Cladocera*).

Seed shrimps (*Ostracoda*-Podocopa).

Copepods (*Copepoda-Eucopepoda*).

Scuds, sideswimmers (*Malacostraca- Amphipoda*).

Crayfish (*Malacostraca-Decapoda*)

The trouble-making crayfishes, *Orconectes virilis* (Hagen) and *Procambarus clarki* (Girard) are species brought in from east of the Rockies, mainly from the southern or midwestern states. Unlike their western cousins, they are extensive burrowers and find ideal conditions in earthen irrigation ditches and flooded rice fields—they are widely distributed and have multiplied rapidly in many parts of California, including rice-growing areas. When abundant, they do extensive damage to irrigation systems by burrowing in ditch and levee banks, and especially around head gates where they often congregate. Muddy water, broken levees, and chimney-shaped holes along the banks and levees indicate crayfish infestations. Encased in their moist burrows these species can, unlike native species, survive long dry spells.

Control. Experimental field tests have demonstrated the effectiveness of certain new organophosphorous insecticides, but recommendations cannot be made until they become registered for use. No chemical control is currently suggested.

Fig. 41. Left: adult of the red crayfish, Procambarus clarki **(Girard), a common inhabitant of rice fields. Fig. 42. Right: burrow of red crayfish in rice check.**

MAJOR BIRD PESTS

In the past, migratory waterfowl and blackbirds caused considerable damage to rice fields. Today, through the efforts of the U.S. Fish and Wildlife Service, the California Department of Fish and Game, and University of California, damage from migratory waterfowl has been reduced to insignificance, practically speaking. Refuges providing alternate food sources are responsible.

Birds cannot be treated as other pests are—waterfowl are important as game birds, and every effort has been made to reduce agricultural depredations without harming the birds themselves. Most non-game birds are protected because of their value to agriculture, and because of the esteem in which they are commonly held. Only when the more common species (such as blackbirds) do considerable and obvious damage has it been possible to obtain legal sanction to destroy them.

Waterfowl as rice pests

The central valleys of California are the fall and winter home of some ten million waterfowl, most of which are migratory and spend only a few months annually in the state. Before the development of irrigated agriculture in California, great expanses of marshland provided a wintering ground for millions of birds and a briefer stop-over for millions more en route to Mexico. As California's natural marsh areas became smaller, competition between birds and producers of cereal grains increased even though the numbers of duck and geese declined.

Countering this trend was the increase in irrigated agriculture, and this is demonstrated strikingly in rice-field plantings. From the birds' standpoint rice fields were not merely substitutes for shrinking marshlands—they were better than the original marshes. Food was provided in abundance, and circulating water of the right depth was amply provided. These facts explained the heavy depredations of waterfowl on rice in the 30's and 40's, but they also suggested the solution to the problem of waterfowl-rice grower competition. In the mid-forties the U.S. Fish and Wildlife Service began a program of expanding existing refuge sites to provide food and water for waterfowl. The idea caught hold rapidly, and with the cooperation of the California Department of Fish and Game more waterfowl feeding and resting areas were acquired.

At the present time, federally operated "Waterfowl Management Areas" in the rice-growing areas comprise about 20,000 acres (Sacramento, Colusa, Sutter and Merced areas). The state operates the 6,000-acre Gray Lodge waterfowl management area near Gridley. The four named areas in the Sacramento Valley are strategically placed for maximal protection to both crops and birds. Two state-operated management areas in the San Joaquin Valley (Mendota and Los Banos) also provide large acreages well placed in relation to the Merced Waterfowl Management Area. Other management areas (Napa marshes, Grizzly Island, and San Luis Wasteway) are not immediately adjacent to rice-growing areas but do have some effect in siphoning off excess numbers of birds in the valleys. This is also true of many private gun clubs.

The grower must do certain things to ensure that birds use the areas provided for them. Most growers believe that frightening off flocks and keeping them off until after harvest is the best way to do this—but unless every flock has a place to go frightening devices can't help everyone.

For best long-range results, it is best to guide flocks of waterfowl to the management areas. This is called "herding," and the other phase of reducing waterfowl depredations is known as "frightening." Doing both gives some lasting protection, but in practice frightening results in most birds ultimately settling on management areas. The following devices and procedures can be used in frightening birds.

Mechanical frightening devices. These are scarecrows, strings of cloth, wind-operated spinners, and similar devices. They are not adapted to large-scale rice farming and are therefore not recommended.

Exploding charges. Sound is enough to repel birds, but birds are frequently

killed or crippled by normal shell loads. The United States Fish and Wildlife Service has perfected a 12-gauge charge which fires a projectile that explodes. A double explosion results—one at firing, the other about 100 yards away, but no shot is present in the charge. Reports on this devise and its usefulness are encouraging (consult your game warden or Fish and Wildlife Service agent about obtaining these shells).

Firecracker strings with slow-burning fuses are available from the Fish and Wildlife Service, but this method of frightening is not applicable to most rice-field situations.

Stationary carbide "guns" which can be set to fire at regular intervals are available now from a number of suppliers. The sound produced will frighten birds initially from areas up to 40 acres in size. The guns must be serviced regularly, however, and birds appear to become accustomed to the sound in a few days' time. It is therefore necessary to use them in one place as little as possible and to move them frequently, perhaps every 2 to 3 days.

Lights. Revolving beacon lights have been used in the Imperial Valley to repel pigeons at night. Inexpensive war surplus lights have been used successfully. These beacons are not suitable for rice fields, but are for other rice-area crops.

Herding with aircraft. Flocks of ducks and geese can be guided away from rice fields by low-flying aircraft and most crop-dusters will contract to herd flocks of waterfowl to management areas. Pilot biologists of the U.S. Fish and Wildlife Service also do this if depredation is severe. If you plan to herd ducks and geese, notify your game warden in advance.

About half of the fall population of ducks are sprig (pintails), but normally only their early flights (late August, early September) cause damage. If large flights arrive early and crop ripening has been slower than normal, it is possible that food in the management areas may not be adequate—so special attention must be given to herding in such years. Normally this is not the case, and there has been little damage in the last few years even with early flights of sprig.

OTHER BIRD PESTS

Coots (mudhen; white-bill) cause little total damage to rice—their chief damage is to sprouting cereal crops in winter and early spring. Some of our coot population is resident; a large part is migratory. Resident birds have paired off for the nesting season by the time rice planting begins, and the migratory population has flown northward by late March. The result is a low concentration of birds during most of the rice-growing season. Coots usually prefer open water and rice fields provide very little during the growing period after stand establishment. Only after harvest is there much likelihood that large numbers of coots will congregate on or near rice fields. Coots are considered migratory game birds and a permit is needed to kill them. Unfortunately, neither frightening nor herding is too effective with them and damage to some crops continues to occur.

Blackbirds. Only the red-winged species constitute a threat to young rice; the yellow-headed blackbird and the Brewer blackbird (no bright colors) cause less damage to seedlings. If a large colony of the red-winged species is nesting nearby, some steps to reduce the numbers of birds may be necessary. This can be done by shooting (permit not necessary) and poisoning (consult your County Agricultural Commissioner if you intend to use poison). Late in the growing season large

flocks of the birds may settle in a field, shattering panicles and breaking stems. The best frightening device is a 12-gauge shotgun. Late-season poisoning may reduce numbers somewhat, but is otherwise not too effective (doves are very susceptible to poisoned baits put out for blackbirds, and every effort should be made to avoid harming them). Other birds may also be susceptible to poisoning.

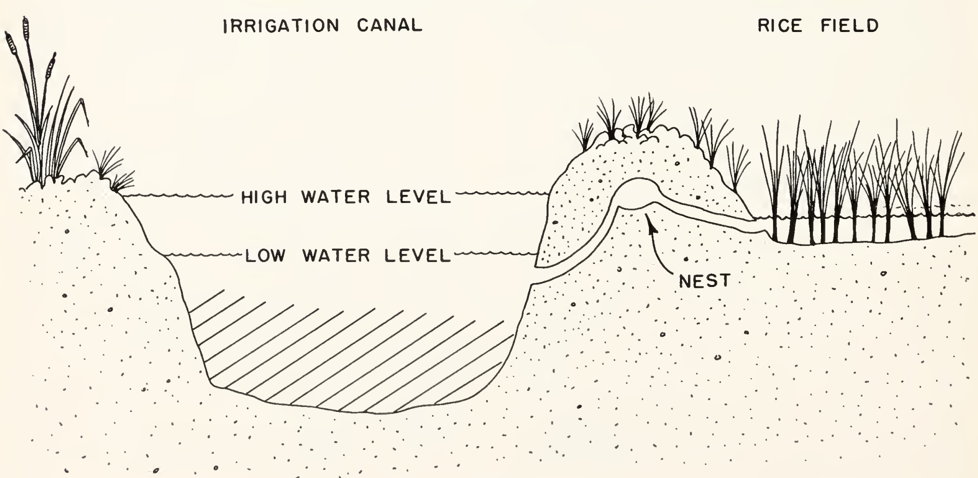
MUSKRATS AND NUTRIA

The nutria (or coypu), an aquatic rodent resembling the muskrat, burrows into banks of leeves and irrigation canals and destroys a variety of wild and cultivated plants. It is two or three times the size of the muskrat, and can be recognized by its rounded tail and the conspicuous orange enamel on its incisor teeth. The nutria is barely established in California and apparently has not seriously invaded the rice-producing region, but in states where it is plentiful it is devastatingly destructive. Presence of nutria should be reported to the Department of Zoology, University of California, Davis.

The muskrat has a dense chocolate-colored fur, partly webbed feet, a long, ridged, naked tail, and attains a weight of 1½ to 2½ pounds. Evidence of its presence and feeding is usually noted by seeing the burrows and the muddied waters and floating cattails, tules, or other marsh plants around their entrances; food remains, such as clam or crayfish shells or cattails, may be seen. Two converging lines of ripples across a stretch of quiet water may indicate a semisubmerged muskrat swimming. If alarmed, it may dive; in clear water it can be followed by the conspicuous silvery film of air surrounding its body. On land the rodent is ungainly—the legs are placed close to each other so that it seems to be raised up when running. The gait is slow and the rat seems to have difficulty in maintaining its balance.

Muskrats burrow near headgates and through levee banks, thus causing loss of impounded water and untimely flooding of dry land; they also dig tunnels at the edge of canals and ponds. The tunnels resemble those of crayfish, and sometimes may actually be enlargements of them.

Fig. 43. Cross-section of an irrigation system threatened by a muskrat burrow.



During the growing season when rice fields are flooded, one or several muskrats may build a tunnel system in a levee and from this they forage in search of the underground parts of cattails and tules. Tunnel entrances are usually below water level, with the nest chamber at a high level; consequently, when the water level is raised the tunnels let water through the levee.

Burrows also may be dug along a check box or drain, thus permitting irrigation water to by-pass these conduits and cause loss of water. Levees perforated by numerous tunnels are weakened, particularly when the nest chambers are close to the surface, and frequent cave-ins and complete breaks in the levees are the result. Fortunately, damage to the rice plant itself is not common, as only occasionally do muskrats cut off plants when foraging or tunneling.

Control of muskrats. Preventive measures include strengthening levees, enlarging check boxes, and using levees and canal banks for grazing. Cattle grazing on the banks of canal levees trample tunnels and nests, and often cause the rodents to emigrate. They can also be destroyed by trapping or poisons or, indirectly, by eliminating vegetation providing feed.

A checkbank with a base of 6 feet offers considerably more resistance to erosion in muskrat burrows than does a narrower bank. A large check box (2 feet wide, 4 feet long, and 18 inches high) constructed of 2-inch lumber tends to discourage the adjacent tunneling by muskrats.

Trapping is a simple and satisfactory method for controlling particularly destructive muskrats. A #1 steel trap should be placed near the water surface at the burrow entrance and anchored to a stake in the water. If levees have been damaged by muskrats, the rodents should be trapped before permanent repairs are made.

Poisoning muskrats and brown rats is best done by placing poisoned grain in floating bait boxes; these devices place toxic materials where aquatic rodents are most likely to reach them, and also safeguard game birds and domestic stock. Muskrats have a fondness for climbing on floating objects, and such bait boxes are readily visited. Bait on land is much less effective and is a hazard to pheasants, ducks, and domestic stock.

A bait box need not be identical to the one shown in figure 44, but troughs for poisoned bait, position of troughs and entrances, roof, small outer platform, and tightness of construction should be as suggested. Smaller size results in an unstable box in which the bait cannot be kept dry. Floats should be of 2 × 6 redwood.

Muskrats accept grain, fruit, and vegetable baits, but grain baits are probably the easiest to handle, and rolled barley and rolled wheat seem to be the most acceptable. Other rodent poisons are not suggested for muskrats. An initial kill may be obtained, but other muskrats quickly invade the poisoned area and soon a bait-shy population builds up.

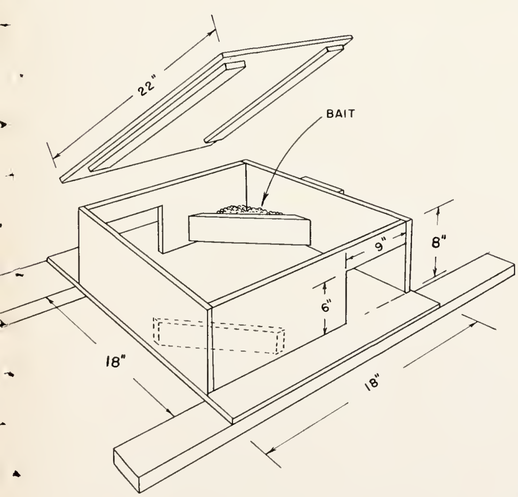


Fig. 44. Floating bait box of proper size for poisoning muskrats and brown rats. Material is 1-inch lumber and waterproofed plywood. Paint will give longer box life.

ACKNOWLEDGMENTS

The two color plates have been prepared by Mary Foley Benson from living specimens.

The authors express their appreciation to Thomas D. Mulhern for permission to use the photographs on mosquitoes, and to Vincent Chang for the crayfish photographs.

Rollo Darby furnished the drawing of the chironomid larva and assisted in preparing the section on midges.

GLOSSARY

Angulate. Forming an angle; when two margins or lines meet in an angle.
Carapace. The hard covering of the thorax in Crustacea.
Chironomid. One of a group of small flies (family Chironomidae) which breed in rice fields and other aquatic situations.
Coleoptera. An order of insects, the beetles.
Culicine. A group of mosquitoes (Tribe Culicini) which includes the widespread genera *Culex* and *Aedes.*
Dorsal. Of or belonging to the upper or top surface.
Elongate. Drawn-out; much longer than wide.
Instar. The appearance of an insect between molts; as first instar, second instar, etc.
Larva (plural, larvae). The active feeding stage(s) of insects having complete metamorphosis and differing materially in appearance from the other stages (egg, pupa, adult).
Mandibles. The stout and tooth-like jaws of most chewing insects.
Metathorax. The third or most posterior segment of the thorax of insects which bears the hind legs and second pair of wings.
Morphological. Relating to form and structure as opposed to function.
Overwinter. Carrying through the winter; usually in a resting stage (such as the pupa) but occasionally as eggs, larvae or adults.
Oviposition. The act of depositing eggs.
Panicle. A loosely branched pyrimidal flower cluster.
Parthenogenetic. Reproduction without fertilization.
Pupation. The act of becoming a pupa, a resting, inactive stage in the higher insect groups.
Rotifers. Minute to microscopic aquatic animals with a characteristic ring of cilia on the anterior end.
Sclerotic. The hard parts of the insect skeleton; formerly (and still) called chitinous.
Spiracles. External breathing openings in insects and other arthropods.
Subspiracular. Below the breathing openings (spiracles) of the insect body.
Substrate. The base (such as the soil) on which an organism lives.
Supraspiracular. Above the breathing openings (spiracles) of the insect body.

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